EXECUTIVE SUMMARY

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The South Fork Tolt Municipal Watershed (SFTMW) is the area draining to the South Fork Tolt Reservoir, from the South Fork Tolt Dam upstream to the headwaters of the South Fork Tolt River (Figure ES-1). The SFTMW supplies one-third of the drinking water that Seattle Public Utilities (SPU) distributes to over 1.4 million customers in the Seattle metropolitan area. The *South Fork Tolt Watershed Management Plan* provides a framework for managing City-owned lands in the municipal watershed to provide high-quality drinking water and restore forest ecosystem function, using the most efficient operation and maintenance standards for water supply facilities.

The vision for management of the watershed is as follows: *It is envisioned that the South Fork Tolt Municipal Watershed will remain a crucial part of the Seattle water supply system and be managed through progressive stewardship that promotes excellent water quality and preserves opportunities.*

Four goals were developed to guide management decisions for the SFTMW:

- **Goal 1**—Maintain and protect source water quality and quantity for municipal water supply and downstream ecosystems.
- **Goal 2**—Protect and restore the natural ecosystem processes and resources of the municipal watershed.
- **Goal 3**—Protect the cultural resources of the municipal watershed.
- **Goal 4**—Manage the municipal watershed based on social, environmental and economic considerations.

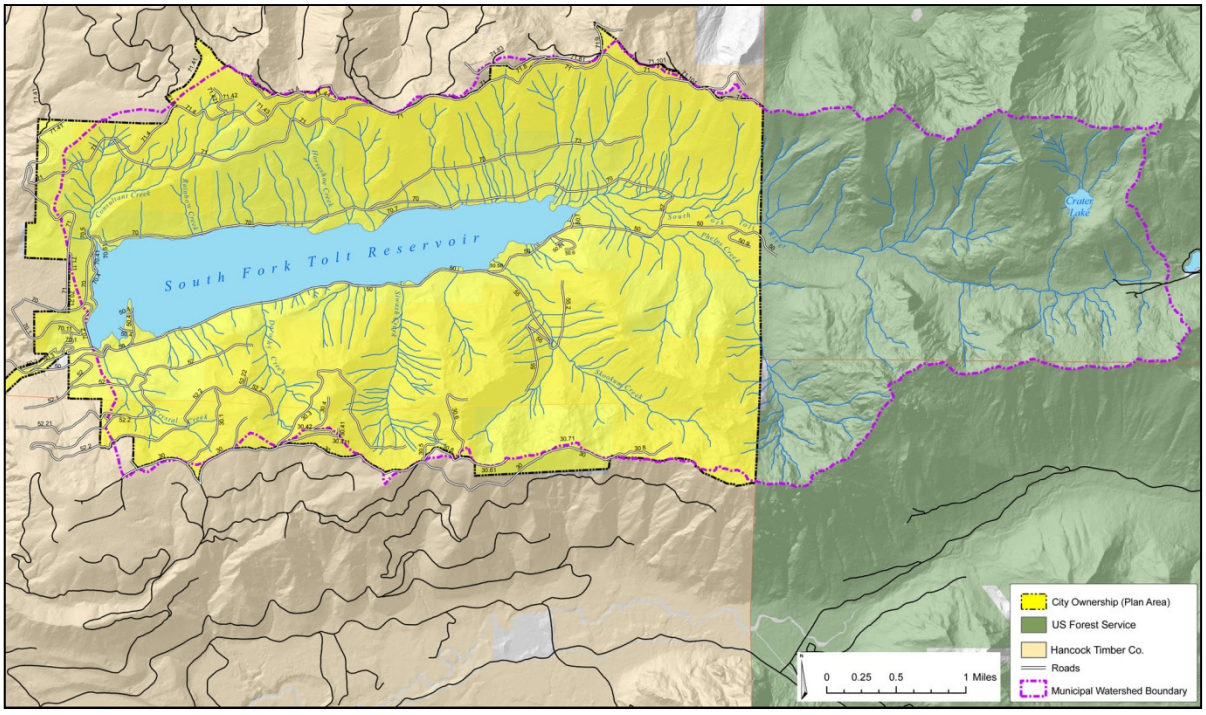


Figure ES-1. South Fork Tolt Municipal Watershed

The Plan describes current conditions, current issues and recommended actions for the SFTMW in the following technical areas:

- **Watershed Protection**—Fire prevention, access control, watershed posting, patrols and incident response, water quality monitoring, issues associated with federal land within the SFTMW, shared road-use agreements with the neighboring private landowner, and mining claims within and near the municipal watershed;
- **Forest Resources—**Forest protection and restoration to improve habitat for wildlife and fish and maintain water quality;
- **Aquatic Resources**—Fish distribution and habitat, channel and wetland processes, landslides and sediment delivery, riparian conditions and restoration treatments, sensitive resources, road erosion, hydrology, and water quality;
- **Fish and Wildlife**—Current and anticipated future habitat to support fish and wildlife needs into the future, the need for monitoring and research, impacts on habitat from past and present management activities;
- **Invasive Species**—Early detection/rapid response protocol to guard against invasive species infestations; efforts to control invasive species;
- **Cultural Resources**—Inventory work to document and map known cultural resources, and guidelines and policies for working in and around cultural sites in the municipal watershed; and
- **Transportation**—Access needs and recommendations to maintain a limited road network to support these needs (including neighboring property access needs governed by the shared Road Use Agreement discussed below), with a schedule to decommission the remaining unnecessary road segments.

HISTORY AND GENERAL DESCRIPTION

The SFTMW is 35 miles east of Seattle on the western slope of the mid-Cascade Range, near the towns of Carnation and Duvall. The SFTMW encompasses the 12,107-acre drainage area upstream of the South Fork Tolt Dam. The western 8,339-acres of the municipal watershed are City-owned and managed, and the eastern 3,708 acres are National Forest System lands administered by the Mt. Baker-Snoqualmie National Forest. The City-owned lands within the SFTMW are closed to public access.

The City of Seattle purchased its water rights to the Tolt River drainage basin from the Mountain Water Company in 1936. Logging by the Weyerhaeuser Company in the reservoir area began around 1946 and continued until 1957. An extensive forest road system was constructed to support logging activities and construction of the water supply infrastructure. Intense logging within the reservoir area occurred between 1953 and 1957. Timber harvest occurred over much of the municipal watershed until the mid-1990s. Some timber harvest has also occurred on National Forest System lands administered by the Mt. Baker-Snoqualmie National Forest within the municipal watershed.

In 1959, an agreement known as the "Watershed Operations Agreement" was executed between Weyerhaeuser and the City for the exchange of 1,400 acres of land to be used for the South Fork Tolt Reservoir and pipeline construction. An agreement for shared road use and maintenance was also executed in 1959. Following dam construction in 1963, the resultant reservoir inundated several miles along the former main stem of the South Fork Tolt River as well as the lower portions of numerous tributary streams. The City began diverting municipal-supply water from the South Fork Tolt River in 1964. The South Fork Tolt Reservoir is the primary storage reservoir in the Tolt water system, holding 18.3 billion gallons (56,160 acre-feet) of water. The City of Seattle completed negotiation for acquisition of all Weyerhaeuser-owned lands in the SFTMW in 1997. In 2000, the Tolt Filtration Plant came on-line, providing ozonation and ultraviolet light disinfection, and carbon filtration, to the water supply originating from the South Fork Tolt Reservoir.

The City currently maintains relations with just two major neighboring landowners (Figure ES-1):

- The National Forest System lands within the SFTMW are managed to be consistent with the 1990 Mt. Baker-Snoqualmie Forest Plan, as amended.
- Hancock Forest Management, Inc.—This private owner purchased the Snoqualmie Tree Farm from Weyerhaeuser in 2003. Most of the land contiguous with the west half of the SFTMW, and most of the land in the adjacent drainages to the north and south, is owned and managed for commercial forest products by Hancock Forest Management Inc. King County owns the development rights to the land sold to Hancock at that time. Shared road use and conduct of parties while passing through neighboring lands are formally addressed through the Watershed Operation Agreement and the Road Use Agreement.

WATERSHED PROTECTION

A comprehensive management plan for watershed protection includes active on-site patrols and surveillance, strict access and control measures, closed gates, a workable lock and key system, posting of boundaries, fire prevention and suppression, emergency response capabilities, continued data collection, and sanitation facilities. Watershed protection also requires coordination with neighboring property owners on access and land use issues that can affect conditions within the municipal watershed.

Key Issues

The following are the key issues related to watershed protection in the SFTMW:

- Current facilities and level of service for fire prevention and suppression in the SFTMW are inadequate in the following areas:
  - Industrial Fire Precaution Level (IFPL) signage does not exist at all SFTMW entry points to inform contractors of daily fire danger level.

  - Staffing and fire-fighting equipment are insufficient to perform fire patrols on days of extreme fire danger, to promptly update IFPL signs, and to respond to fire starts.
  - Local fire departments cannot provide initial response to the SFTMW in a timely manner due to some deteriorated road conditions, gated access, and the remoteness of its location.
- Access and control infrastructure and procedures do not fully support SPU security requirements for watershed protection in the following areas:
  - Gates that control access to the SFTMW from the west are not up to SPU standards.
  - There are no gates at the east end of the SFTMW on National Forest System lands.
  - Boundary posting is absent or deteriorated to a point of being illegible in most locations along City-owned boundaries of the SFTMW.
  - Keys to SFTMW gates are controlled and issued from the Operations Control Center in Seattle, but permits are issued by staff within the Watershed Services Division at Cedar Falls. Key-issuance protocols and padlock installations are not handled in a consistent manner, which results in reduced level of access control.
- There are no portable or semi-permanent toilets located upstream from the dam.
- SPU Watershed Protection staff does not conduct daily physical monitoring of critical infrastructure assets (infrastructure necessary for the delivery of water).
- No emergency supplies (fire response trailer, spill response drums) are located in the SFTMW.
- Adequate staffing levels are often not available to staff two-person water quality and quantity sampling teams.
- There is potential for activities on the National Forest System lands within the municipal watershed that may be incompatible with the protection of the municipal water supply.
- The Watershed Operations Agreement and Road Use Agreement have provided a general administrative framework for coordinating with Hancock Forest Management, but they have never been tested in a technical or legal sense.
- The City has no certainty and only limited effective control over the future disposition and activity on existing mining claims in the municipal watershed.
- There is a lack of clarity about policies, procedures, roles, and responsibilities associated with watershed protection services for the SFTMW.

Recommended Actions

The following recommended actions represent a conservative approach to bringing watershed protection service levels in line with SPU standards while acknowledging the remote location of the SFTMW and relatively low level of management activities that will take place within the SFTMW.

- There is a need for a comprehensive Tolt Water Supply Security and Protection Plan, including areas downstream of the dam.
- IFPL signs should be installed at access gates on the 50 and 70 Road entrances to the municipal watershed.
- A fire trailer should be stationed at the Vista House above the dam during fire season, equipped with a 300-gallon water tank, 13-horsepower pump, and a minimum of 300 feet of hose. The trailer should be stored in a simple shelter or garage to reduce its exposure to weather and ensure proper operation of pumps and equipment for immediate fire response.
- Centralized key and padlock administration should be implemented that is consistent with SPU key-management policies, combined with the requirement that all non-SPU users of the municipal watershed obtain and display a valid permit. Cyber-locks should be installed on all gates from the Kelly Road to the municipal watershed boundary and at all gates entering the Municipal Watershed.
- Nine existing gates should be replaced to meet current SPU security standards, and several new gates to control access should be installed. Proper signage that conforms to current SPU standards will need to be installed on all gates.
- "No Trespass" signs should be posted every 100 feet around the perimeter of City-owned lands in the SFTMW. The posting line will require yearly maintenance to keep up its appearance and replace worn and weather-damaged signs.
- Semi-permanent portable toilets should be installed and maintained at remote locations of the municipal watershed upstream from the dam, and portable toilets should be ready and available to be moved to locations where they will be most needed depending on activities in the watershed.
- All non-SPU individuals entering the SFTMW must be informed of their obligations within the watershed, including compliance with SPU watershed access and control regulations, which require sanitary facilities at all work sites and prohibit any activities that could contaminate the water supply.
- Proactive infrastructure checks should be conducted to identify problems as they arise.
- Incident response, investigation, resolution, reporting, and follow-up capabilities will need to increase to meet SPU security and emergency management policy.
- A properly outfitted 12-foot rescue cache trailer should be staged at the Vista House. It should contain an inventory of medical supplies, rescue equipment, emergency survival supplies, lighting, communication, food, water, and spill response supplies. Fifty-five gallon spill response drums should be purchased and deployed at the six bridge crossings on reservoir perimeter roads.
- SPU should evaluate the City's options for managing the risk of incompatible land uses in the municipal watershed and assess the costs, benefits, risks, and feasibility of acquiring federal lands in the SFTMW as a means to reduce the risk of future incompatible land uses.

- The Watershed Operating Agreement and Road Use Agreement with Hancock Forest Management, Inc. should be updated to address all current conditions and issues.
- SPU must determine whether any mining claims in the SFTMW were improperly classified as active because they were filed after the effective date of the mineral withdrawal mandated by Public Law 97-350. SPU should also evaluate the City's options for managing future risk associated with active claims.

FOREST RESOURCES

By the time that harvesting of old-growth forests in the SFTMW ended in the 1990s, three-quarters of the forest in the basin had been harvested. Regeneration of secondary forests was slow except on productive sites in the valley bottom. Large areas on the south side of the basin remain in early-successional stages due to shallow soils and poor growing conditions. The remaining old-growth forests in the City-owned portion of the SFTMW are located on steep rocky slopes, mostly in the Phelps, Skookum, and Siwash subbasins.

Forest management goals of the City-owned portion of the SFTMW contrast sharply with the management of forest on neighboring lands. Lands owned by Hancock Forest Management to the north, south, and west are managed to maximize timber production using even-age stand management. The forest lands to the east are managed by the USFS and are predominantly old-growth forest and sub-alpine shrub vegetation, with no current forest management activities, and no expectation for activities in the future.

Key Issues

Past forest management has drastically disturbed forest and altered natural ecosystem functions in the watershed, such as forest habitat, productivity, and sediment delivery and transport in streams. The following are the key issues related to forest resource management in the SFTMW:

- Young forests with limited tree species composition and homogeneous forest structural conditions have lower habitat value, biodiversity, and summer base flows in tributary streams.
- The reduced tree species diversity and low number of large residual standing and down dead trees may reduce the resilience of the ecosystem to withstand or recover from further disturbance or adapt to gradually changing environmental conditions that occur from climate change.
- The removal of mid-slope roads and roads on steep slopes in the southeast portion of City-owned lands in the basin creates operability constraints for possible forest management. These areas should be excluded from active management or be considered for hands-only restoration treatments.
- The SFTMW's position between industrial forest lands (mostly early seral forest) and National Forest (mostly late seral forest) creates a strong contrast in forest age distribution and structure on the landscape. This places a greater importance on the management of

SFTMW forest lands to create a landscape more effective in fostering biodiversity and providing resilience in the face of environmental changes and disturbance.

Recommended Actions

An active program of restoration treatments in second-growth forests is recommended to facilitate the recovery of ecosystem functions and increase the resilience to disturbance. Objectives of this program are as follows:

- Protect and promote erosion prevention and sediment retention functions of natural forested landscape.
- Promote the development of late-successional forest structures.
- Provide wildlife habitat elements.
- Sell surplus trees to offset costs of restoration activities.
- Maintain reserve areas including non-managed remnants of old-growth, inaccessible areas of the watershed, and unstable slopes.

Habitat restoration will be accomplished through a range of treatments:

- **Restoration thinning**—Thinning to 150 to 250 trees per acre, and creating canopy gaps (for young dense forest 15 to 40 years old)
- **Ecological thinning**—Variable density thinning to 100 to 240 trees per acre, including canopy gaps and unthinned skips (for older dense forests with closed canopy)
- **Planting**—Planting site appropriate minor tree species to increase species diversity
- **Understory thinning**—Thinning to 100-250 trees per acre (for young dense trees in understory)
- **Habitat enhancement**—Top or girdle clusters of large trees per acre (for older dense forests with few snags)

The proposed management plan establishes acreages for each type of treatment to be carried out each decade through 2086. Treatments for specific areas within the SFTMW will be selected based on the following criteria:

- Defined management zones with associated restoration goals,
- Potential productivity of the site,
- Potential for coordinating with other restoration activities, and
- Forest stand conditions.

Under the recommended management approach, more than half of the forested lands of the SFTMW should consist of multi-story forest habitat by about 2027.

AQUATIC RESOURCES

Protection of drinking water quality and protection of aquatic habitats both require protection of vegetation near water bodies and minimization of sediment delivery to streams from upland activities. Streams, lakes, ponds, and wetlands function as an interrelated system that provides water and aquatic habitat for a variety of animals.

Nineteen tributary subbasins have been delineated within the SFTMW. Major tributaries to the South Fork Tolt Reservoir include the main stem South Fork Tolt River (including Phelps Creek), and Skookum and

Siwash creeks. Consultant, Rainbow, and Horseshoe creeks and numerous unnamed drainages enter the reservoir from its north side, while Crystal, Dorothy, Siwash, Chuck Judd, Skookum, and several unnamed creeks enter the reservoir from the south. Almost 80 percent of the total length of streams consists of small, steep tributaries.

Lake habitat in the SFTMW includes the South Fork Tolt Reservoir and Crater Lake. Reconnaissance surveys of the SFTMW indicate very few wetlands in the steep terrain of the basin. Wetland habitat is limited to areas associated with the delta area of the South Fork Tolt River at the eastern edge of the South Fork Tolt Reservoir, several small depressional wetlands on topographic benches along the south ridge of the SFTMW, and meadow systems in the headwater areas of the main stem South Fork Tolt River.

Streams and wetlands in the SFTMW have been impacted to various degrees by past timber harvest and activities such as road building. These activities affected such watershed processes and conditions as sediment delivery, riparian, vegetation and recruitment of large woody debris (LWD), all of which directly affect aquatic habitat and resources. The result of these practices has been that many landslides delivered into the South Fork Tolt Reservoir, the creation of barriers to the movement of fish and wildlife, and chronic delivery of road-generated fine sediment to streams and the reservoir. The SFTMW has experienced only one known landslide since 1997—given that the majority of previous landslides were associated with roads, the program of road decommissioning appears to have been effective in reducing and potentially eliminating most landslides. These results suggest that current landslide rates may be approaching natural or background rates in the SFTMW, however sediment from former landslides continue to move through the system into the reservoir.

Identification of critical aquatic resources required a determination of the following:

- **Impacted Areas**—Areas where key processes are most likely to have been impacted by forest management;
- **Sensitive Resources**—Areas that are most sensitive to the impacts of forest management; and,
- **Linkages**—The overlap between impacted areas and sensitive resources, indicating resources that likely have been severely degraded as a result of past management activities.

Key Issues

The following are the key issues associated with aquatic resources in the SFTMW:

- There is poor near-term LWD recruitment potential in large, low-gradient, fish-bearing streams.
- Fine sediment is being delivered to streams from some portions of the SFTMW road system.
- Roads within or adjacent to wetlands can act as barriers to movement of amphibians using these wetlands as habitat.
- Improperly installed or poorly maintained culverts represent fish-passage barriers on streams.
- Timber harvest and road construction have also resulted in bank instability,

channel widening, and turbidity within the reservoir.

- Timber harvest and road building in the SFTMW can result in an increase in the frequency of landslides, which deliver sediment to fish-bearing streams and the reservoir.

Recommended Actions

Sediment impacts on the City's source water were a primary consideration in formulating recommended actions related to aquatic resources. Sediment contribution to the reservoir negatively impacts the City's water supply through reservoir infilling as well as higher filtration costs. Restoring aquatic resources will hasten recovery of the disturbed system to a more natural level of sediment contribution. The recommended actions fall into four general project types:

- **LWD placement projects**—Construction of engineered log jams to deflect flow away from floodplain channels tributary to the South Fork Tolt River immediately upstream of the reservoir would reduce the likelihood of main stem channel avulsion and partial or complete scour of the floodplain channels. Addition of LWD to one of these floodplain channels would also improve fish habitat.
- **Headwater Riparian Thinning**—Riparian thinning involving directional tree-felling toward steep gradient, high sediment producing streams to create needed sediment storage sites, thereby reducing the chronic disturbance to downstream habitat, as well as moderating the release of sediment into the reservoir.
- **Riparian treatments along fish-bearing streams**—Increasing the growth rate of existing conifer trees by thinning and by under-planting conifer trees in deciduous-dominated riparian stands will increase future LWD recruitment potential. To address this issue, riparian zones associated with the larger fish-bearing streams will be further evaluated to assess the efficacy of active restoration involving riparian thinning and under-planting.

FISH AND WILDLIFE

Habitat available for fish and wildlife in the City-owned portion of the SFTMW includes young forest, the reservoir, and various special habitats such as rock outcrops, cliffs, talus slopes, meadows, wetlands, and shrub-dominated sites. Available forest habitat was profoundly altered from natural old-growth forest conditions, leading to a lack of old-growth-dependent species in the SFTMW. Although current information on fish and wildlife species in the watershed is very limited, the following information is available:

- Old-growth-dependent species such as northern spotted owl, marbled murrelet and northern goshawk are not known to occur on the City-owned land within the SFTMW. Northern spotted owls and marbled murrelets have been documented on USFS-owned land within the SFTMW.

- Black-tailed deer are known to inhabit the SFTMW, but the Washington Department of Fish and Wildlife (WDFW) has no records of elk being present in the entire South Fork Tolt basin, either historically or at present.
- Wolverines are not likely to be found in second-growth forest of City-owned lands within the watershed.
- The South Fork Tolt Reservoir provides one of the few undisturbed lake environments in western Washington where common loons can reproduce without high levels of human activity and associated disturbance. Common loons regularly nest on the reservoir, and SPU staff annually deploy and monitor an artificial nesting platform to aid the loons in overcoming the difficulties of water level fluctuations.
- A variety of amphibian species depends upon the small ponded depressional wetlands in the SFTMW for breeding and rearing habitat.
- The fish community using habitat within the SFTMW upstream of the reservoir is relatively simple, consisting of cutthroat trout, cutthroat/rainbow hybrids, and torrent sculpin. Existing survey data indicate that fish use is limited primarily to the reservoir and lower reaches of tributary streams, although the upper limit of salmonid distribution has not yet been definitively determined. Anadromous salmonids have not historically had access to this portion of the Tolt River Watershed due to a natural fish passage barrier approximately one-third mile below the South Fork Tolt Dam (Williams, 1975).

Key Issues

The following issues relate to the need for greater information about the habitats and populations for fish and wildlife in the watershed:

- Some information about the amount and distribution of important habitats and special habitat features such as meadows, rock outcrops, talus, cliffs, snags, and downed wood was collected during data collection for this plan; however, detailed documentation of special habitat conditions has not yet been generated.
- There is little known about the presence and distribution of most fish and wildlife species, such as northern spotted owl, marbled murrelet, northern goshawk, and amphibians.

The following issues relate to protecting habitat in the SFTMW:

- Special habitats (meadows, wetlands, old-growth forests) and special habitat elements (snags, downed wood, large branches, and large woody debris in streams of concern) are rare and require protection.
- Habitat associated with known locations of species are in need of protection from disturbance.
- SFTMW management should not exacerbate natural disturbances, such as floods, forest fire, wind-throw, and landslides.
- The effects of climate change on the SFTMW ecosystem are uncertain.

- There is uncertainty whether landscape conditions outside the SFTMW will remain constant. Habitat conditions on neighboring lands affect landscape-scale habitat connectivity for some species.

The following issues relate to restoring essential ecological processes in the SFTMW:

- A history of clear-cut timber harvest has reduced and/or degraded habitat for species of concern in the SFTMW.
- Forest habitat within the watershed should be managed primarily for late-successional forest structure and processes.
- Aquatic and forest restoration should focus on areas such as migration pathways between existing old-growth or late-successional forest habitat, corridors between ponds and upland forests, and connectivity between wetland habitats.
- Special habitat elements such as snags, downed wood, and large branches in forests and large woody debris in streams may be insufficient to support some species.
- Invasive plant species may threaten habitat quality for many wildlife species.
- Minimizing or reducing existing road impacts by road decommissioning and improvements would benefit a variety of species.

Recommended Actions

Fish and Wildlife recommendations were developed following an evaluation of legal requirements, consistency with SPU goals for the SFTMW, and consistency with other Plan components. The following recommendations represent a minimal level of service related to fish and wildlife resources of the SFTMW:

- Mapping and ground verification of Special Habitats should be undertaken.
- The presence and quantity of habitat elements, such as snags and downed wood should be assessed during project planning in all proposed treatment areas in order to protect these features and to potentially increase their abundance.
- Surveys to document the presence of common loon, marbled murrelet, and amphibians should be continued and expanded.
- Efforts to monitor and provide common loon nesting platforms in the reservoir should continue.
- An assessment of northern goshawk habitat quality should be conducted to identify areas where this species could potentially occur.
- If found, nest sites of spotted owl, marbled murrelet, and other listed or sensitive species (e.g., common loon, peregrine falcons) should be protected by implementation of noise and disturbance restrictions within minimum distances of nest sites or occupied stands, depending on the species.
- Pieces of large woody debris occurring on the reservoir delta should be left in place, and cabled if necessary. Large woody debris taken from the reservoir in order to protect the dam should be stockpiled for use in stream restoration.

- Disturbance to the delta from heavy equipment should be completely avoided or at least minimized.

INVASIVE PLANT SPECIES

Invasive species (including terrestrial and aquatic plants, pathogens, insects and other animals) pose significant risks to native biodiversity, fish and wildlife habitat, and basic ecological functioning. Currently, yellow hawkweed and tansy ragwort are the only invasive species documented in the SFTMW that are addressed by invasive species control regulations. However, comprehensive surveys have not been conducted for either of these two plants or for other invasive species. Some invasive plants that could cause ecological damage, but are not legally required to be controlled, have been observed, but not mapped or controlled. These include evergreen blackberry, Himalayan blackberry, Scots broom, bull thistle, and Canada thistle. Most of these plants have been seen along the roads adjacent to the reservoir.

The invasive species control program described in this management plan is part of a larger SPU Terrestrial Plant Invasive Species Management Program for the Utility's major watersheds. SPU will use Integrated Pest Management (IPM) principles to minimize the risk of invasion and to control any invasive species detected. IPM requires an evaluation of each invasive species patch to determine the most effective and cost-effective control methods. It is expected that these will vary by species and site-specific conditions.

Key Issues

Key issues associated with invasive species in the SFTMW are largely associated with future activities and events, many of which cannot be clearly predicted:

- Large-scale natural disturbances such as wildfires would increase the risk of infestation by invasive plants, especially if there is a nearby seed source, as well as pathogens and insects. Because events like this are effectively unpredictable, it is difficult to plan for them.
- Changing management strategies on neighboring properties could significantly alter the risk of invasion by new non-native species.
- Any ground-disturbing work within the watershed will increase the risk of invasion, especially if it is located near an existing plant infestation that could serve as a seed source.
- Climate change is predicted to create conditions that will favor invasive species over native plants because of increased disturbance and higher carbon-dioxide levels in the atmosphere. However, the extent to which this may happen within the SFTMW is unknown.
- Little research has been conducted on the actual impact of specific invasive species on habitat for fish and wildlife species in the western Cascade Mountains.

Recommended Actions

The following recommendations for invasive plant species management in the SFTMW would have the lowest ecological risk, lowest

long-term costs, and highest ecological, social, and economic benefits:

- Implement an early detection/rapid response protocol, which entails surveying a portion of the SFTMW every year, to cover the entire watershed every five years, and treating new infestations immediately.
- Encompass all invasive species survey and control in the SFTMW within the larger Invasive Species Program for SPU's major watersheds.
- Complete plant surveys.
- Complete invasive plant experimental control efforts.
- Utilize Integrated Pest Management (IPM) principles.

CULTURAL RESOURCES

Protecting cultural resources in the City-owned portions of the municipal watershed is one of the primary goals for SPU's management of the SFTMW. A cultural resource management plan (CRMP) for the Cedar River Municipal Watershed established procedures in 2004 to limit and reduce potential conflicts between SPU's primary mission activities and applicable regulations governing cultural resource protection. Although the SFTMW is much smaller and contains fewer known and potential cultural resources, the similarity of cultural resource management issues supports incorporation of the standards and protocols established in the CRMP for the Cedar into the recommended actions in this plan for the SFTMW.

Key Issues

The key issues associated with cultural resources in the SFTMW are as follows:

- Formal guidelines are lacking for compliance with federal, state, and city ordinances to provide protection of cultural resources.
- Protocols regarding unanticipated discovery of cultural resources, treatment of human remains, response to vandalism, and emergency response do not exist for the SFTMW.
- The GIS database is incomplete for known and potential cultural resource information in the SFTMW. This information is needed for cultural resource protection during planned activities, such as bridge replacement or road decommissioning, as well as emergency responses to flooding, fire, and earthquakes.
- Formal guidelines are lacking for information sharing and confidentiality for all parties involved.
- Formal guidelines are lacking for the curation of cultural material.
- City maintenance staff have not been oriented and trained in their responsibility to protect cultural resources and in identification of cultural material that they might encounter.
- No formal system exists to educate contractors and other visitors to the SFTMW about cultural resource protection requirements.

Recommended Actions

The following actions are recommended for cultural resource management in the SFTMW:

- SPU should adopt cultural resource management standards for the SFTMW adapted from the U.S. Secretary of the Interior's *Standards and Guidelines for Archeology and Historic Preservation*. SPU should apply the standards in a reasonable manner, considering the economic and technical feasibility of implementing them within the context of its responsibility for the overall management of the watershed and its other resources.
- The existing GIS database for known and potential cultural resource information needs to be updated as new information becomes available. SPU will soon be conducting a traditional cultural property survey; the results of this survey will be incorporated into the GIS database when complete.
- All SPU staff should be required to consider protection and management of cultural resources in planning for projects or maintenance work in the SFTMW, especially for projects that may involve ground disturbance or vegetation modification. Staff members should review the SFTMW GIS database during the planning stages of any proposed activities to determine if the proposed project area includes identified cultural resources and to determine the area's potential for unrecorded cultural resources.
- SPU should adopt and follow the recommended protocols for the following circumstances:
  - Unanticipated discovery of cultural materials,
  - Treatment of human remains,
  - Response to vandalism, and
  - Emergency response.
- Mitigation through archaeological data recovery, recordation of standing structures, or other measures should be conducted based on the guidance of The Advisory Council on Historic Preservation's *Recommended Approach for Consultation on the Recovery of Significant Information from Archaeological Sites* (64 FR 27085-87, 18 May 1999).

TRANSPORTATION

A functioning forest road system is an integral element of the SFTMW. The basic guiding principle for the future of this road system is to manage the balance between access and impact. The road system provides access for all types of management activities. The road system is also a source of negative impacts on habitat and water quality. The roads must be managed to provide access, while reducing the negative impacts as much as possible. The road system is in place to serve management activities and is not a valuable asset in itself aside from this service.

The historic road network accessed most of the area within the SFTMW, however, many roads in the watershed were decommissioned following the acquisition of lands from Weyerhaeuser. The roads are in a variety of conditions, affecting drivability and stability, and will need ongoing repairs, maintenance

and decommissioning. Extensive road network improvements have been performed since 1993, including decommissioning, surfacing, and reduced usage, and these improvements have significantly reduced many of the adverse impacts of the SFTMW road system. Each road in the SFTMW was classified into one of four categories:

- **Core Roads**—These roads are needed for long-term use. Activities on these roads will be governed by Road Use Agreements. There are 40 miles of core roads in the SFTMW.
- **Temporary Roads**—These roads will provide access for a limited time for projects developed under the watershed management plan. Temporary roads may be needed for five years or until 2060, or any time in between. There are eight miles of temporary roads in the SFTMW.
- **Non-Essential Roads**—These roads have been identified as serving no current or future access needs. They will be scheduled for decommissioning to a standard that will eliminate potential adverse environmental impacts from the road. Three miles of roads are currently classified as non-essential.
- **Decommissioned Roads**—These roads have been decommissioned to stabilize them and reduce future risk of impacts on water quality and habitat. There are 32 miles of decommissioned roads in the SFTMW.

Key Issues

Roads within the SFTMW continue to have both direct and indirect adverse effects including the following:

- Contribution of fine sediments through streams and direct discharge into the Tolt Reservoir.
- Changes in stream channel structure and geometry from increased sediment loads
- Interruption of sediment and wood transport at stream crossings
- Road encroachment into floodplains and riparian zones
- Barriers to fish passage and wildlife migration.

Overall, 50 percent of the active roads in the watershed deliver directly to streams, and isolated erosion features related to roads remain on the south side of the SFTMW.

Improvement and maintenance of roads used by adjacent landowners, and the frequency and nature of their use needs to be addressed in the road use agreements with Hancock Forest Management Inc.

Recommended Actions

The short and long-term need for each road was weighed against its possible impacts on water quality and habitat in addition to the financial cost required to improve, decommission, or maintain it. Recommended actions focus on providing access for management projects and ongoing work, while working to reduce impacts on water quality and habitat. Future road work falls into three categories:

- **Road improvements**—Road improvements address issues such as poor or improper drainage; structural

concerns associated with the cut-slope, prism, or fill-slope; and road shaping and surfacing. Roads are prioritized for improvements based on the capacity of the existing road to provide needed access, the extent to which current conditions are contributing to resource degradation, and the extent to which economically feasible solutions exist to address the critical concerns. Three road segments have been prioritized for improvement prior to 2014. Eight other roads have been given a moderate priority, reflecting those contributing adversely to water quality, but which in their present condition are able to meet SPU's access needs.

- **Maintenance**—Road maintenance represents annual work needed to prevent drainage problems from escalating into larger problems and maintaining road tread to achieve designed drainage characteristics.
- **Decommissioning**—When a road is no longer needed for access, it is reclassified as non-essential and placed on the list of roads to be decommissioned. Road decommissioning commonly involves the removal and relocation of over-steepened and unstable fill, as well as the restoration of natural drainage patterns and stream crossings. Three roads have been identified for decommissioning prior to 2014 because of their adverse impacts to aquatic habitat and water quality, and expensive annual maintenance requirements. Eleven additional roads, classified as non-essential, have been given a moderate priority, and sufficient funds; these will be decommissioned between 2014 and 2025.
- **Road schedule**—A road schedule was developed to prioritize road improvements and decommissioning (Tables 9-3 and 9-4).

Road management standards for maintenance and improvement in the SFTMW will be the same as those used to manage the Cedar River watershed (*City of Seattle Cedar River Watershed Road Management Standards and Guidelines*, Draft, January 2004). These standards address all aspects of road construction, maintenance, and decommissioning. They include work methods, drainage structures, materials, and environmental protection. They describe methods to ensure that all road work is conducted to provide protection of water quality and habitat, reduce road failures, and provide appropriate safe access.

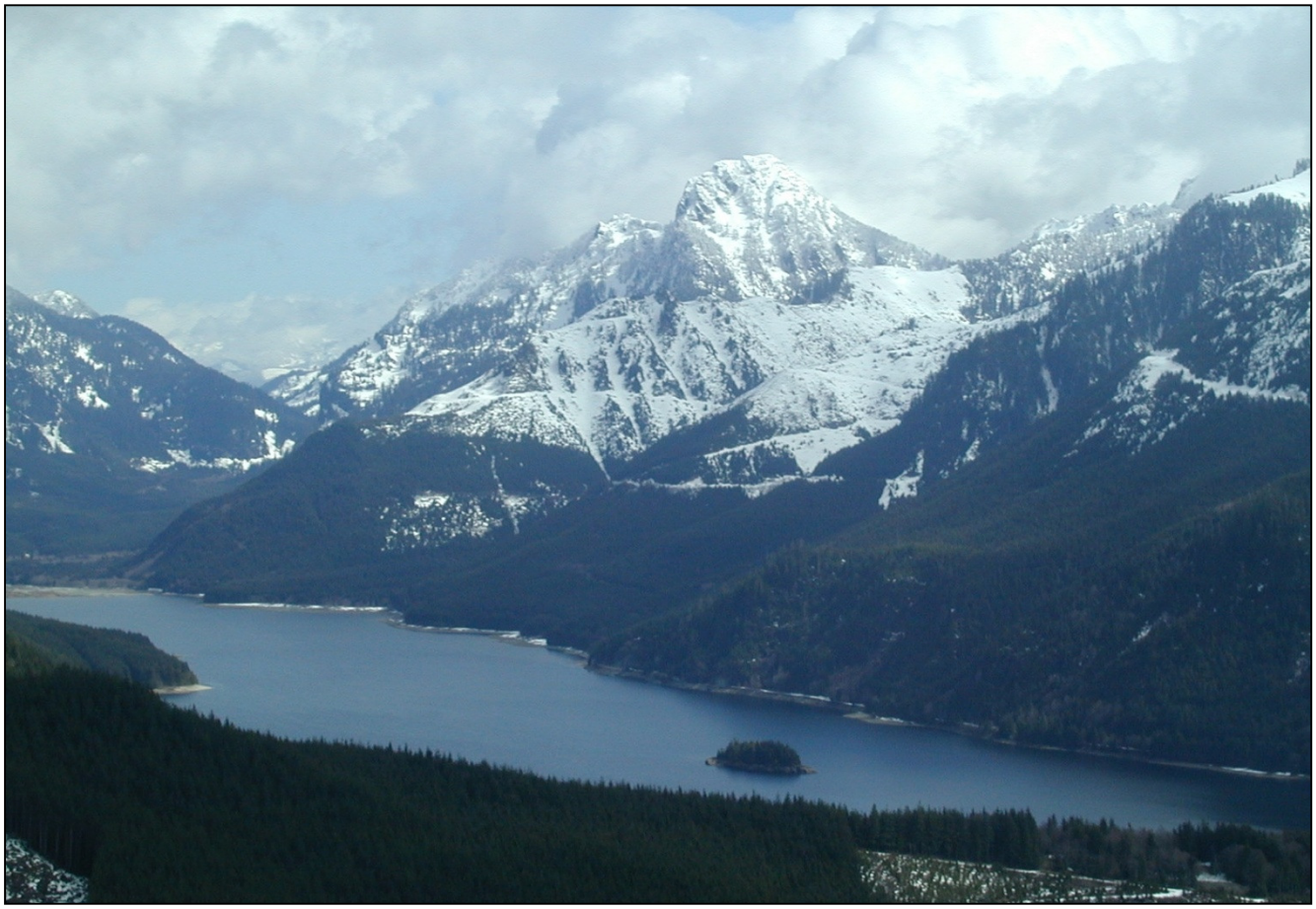
IMPLEMENTATION

The South Fork Tolt Municipal Watershed Management Plan (Plan) will be implemented over a 20-year timeframe and will be reviewed and updated as needed during that time. A complete review and update of the Plan will commence at the end of the 20-year period. The vision and goals of the Plan are fixed; however, the recommended actions are designed to be revised and updated as appropriate, thus providing flexibility with respect to when and how the actions are implemented.

Each recommended action will be included in one or more of the following phases:

- **5-Year Phase**—This phase includes many of the watershed protection actions as well as forest and aquatic resources, restoration actions, and transportation actions pertaining to watershed health and water quality.
- **10-Year Phase**—Many 10-Year Phase actions are subsequent phases or monitoring related to actions initiated in the 5-Year Phase.
- **20-Year Phase**—These actions, although still important, are more integral to achieving other watershed management goals.
- **As-Needed Actions**—As-Needed Actions that are essential to meeting the primary goal are those that are required to occur prior to the design and construction of new structures, initiation of a new activity, or granting of a new permit.

Phasing priorities are related to the ability of the action to help achieve the primary goal of maintaining and protecting source water quality and quantity for the municipal water supply and downstream ecosystems. Actions that are most critical to meeting this goal were assigned to 5-Year Phase or As-Needed Actions.



CHAPTER 4. FOREST RESOURCES

A management plan was developed for the upland and riparian forests in the SFTMW to align the management of forest resources with the following SPU goals for the SFTMW:

- **Goal 1**—Maintain and protect source water quality and quantity for municipal water supply and downstream ecosystems
- **Goal 2**—Protect and restore the natural ecosystem processes and resources of the SFTMW
- **Goal 4**—Manage the SFTMW based on social, environmental and economic considerations.

FOREST RESOURCE INVENTORY

In 2006, a forest resource inventory was performed for the entire SFTMW, including City and National Forest System lands (Atterbury, 2006). Forests under City ownership were classified and accessible areas were sampled, with inventory plots covering 5,024 acres of forest. Approximately 3,737 acres of forest under City ownership is inaccessible and was not inventoried. USFS forest lands (covering 3,697 acres) was classified to stand type but not inventoried with sample plots.

Forest Structure and Composition on City-Owned Land in the SFTMW

Forest Age Class Distribution

Most of the forest lands under City ownership in the SFTMW were historically clear-cut harvested, and the forest age distribution (Figure 4-1, Map 7) reflects that harvest history. Of the forested net acres under City ownership in the SFTMW (7,015 acres, excluding roads, landings, facilities, and the reservoir), 93 percent is managed forest and 7 percent is old-growth forest, mostly in steep rocky areas. The second-growth forests became established through planting, natural regeneration, and advanced regeneration (trees that became established under the canopy of preceding forest stands). Some forest stands were pre-commercially thinned by the prior landowner, and a small amount of commercial thinning may have occurred.

Forest age for previously harvested areas ranges from

Highlights

The forests in the SFTMW are mostly young, second-growth stands established after clear-cut harvesting, with youngest stands at higher elevations. A limited area of old-growth forest remains on some steep rocky slopes. The young second-growth forests lack the diversity of features to provide all the benefits of an older, more diverse forest.

Four forest-management options, representing varying levels of timber harvest and habitat development were evaluated for this plan. The option with the greatest emphasis on habitat development was selected as the preferred forest management plan. This plan includes the following:

- Focus on the long-term development of late-successional forests;
- Obtain revenue for management activities through the sale of surplus timber from thinning to offset costs;
- Prioritize restoration treatments based on identified management zones, site productivity and stand condition, and the potential for coordinating with other management actions in the municipal watershed;
- Employ various forms of thinning and planting to create the desired forest diversity; and
- Complete the proposed program in stages over 70 years.

Forest Resources
The uses and values associated with, attainable from, or closely tied to, forested landscapes; they include aesthetics, fish, forage, recreation, soil, timber, water, wilderness, and wildlife.

Figure 4-1. Age Class Distribution of Forest

Stand
A group of forest trees of sufficiently uniform species, composition, age, and condition to be considered a homogeneous unit for management purposes.

10-year-old stands on higher elevation sites to 55-year-old second-growth stands at lower elevations. As a legacy of the harvest history, stand age declines with increasing elevation. On exposed slopes and along ridge tops, sites may be found with relatively young forest featuring small trees and shrubs. Although sites at higher elevations were harvested 25 years ago, they may only have 10-year-old trees because stand establishment may take several decades on these low-productivity sites.

Forest Species Composition

The sampled stands on the City-owned lands in the SFTMW are dominated in number by western hemlock and Pacific silver fir trees. By board-foot volume, western hemlock is the dominant species (51 percent), and Douglas-fir is the second (31 percent; see Table 4-1). Board-foot volumes in the 40- to 55-year-old stands range from 8,000 board-feet per acre to 37,000 board-feet per acre, with the highest volumes appearing on the lower third of the watershed's slopes, near the reservoir.

Conifers are the primary species in 99 percent of the stands; deciduous trees dominate the canopy in the few riparian areas at the valley bottom. Most of the forest stands are dense with a single canopy layer (most of the foliage is distributed in the upper forest canopy); they support little understory vegetation.

Forest Productivity

Site class is an index of forest productivity and is measured by the height of dominant trees at 50 years of age; Site Class I represents the highest productivity and Site Class V represents the lowest productivity.

Table 4-2 shows the distribution of site class by acres of forest on City lands in the SFTMW. The 2006 inventory found that these forests are dominated by Site Classes III, IV, and V. Site class generally decreases with elevation. The relatively low

productivity in the SFTMW is comparable to other sites in the west-central Cascades.

TABLE 4-1.
DOMINANT TREE SPECIES DISTRIBUTION BY BOARD FOOT VOLUME

Dominant Tree Species	Percentage Volume
Western hemlock	50.8%
Douglas-fir	30.9%
Pacific silver fir	13.6%
Red alder	1.7%
Other species (e.g., big leaf maple, cottonwood)	3.0%

Forest Structure and Habitat

The forests in the SFTMW are dominated by young second-growth stands in the competitive exclusion stage of forest development. Forests in this stage of development are relatively simple in structure and are dominated by a single age class and have a dense single canopy layer. The dense forest canopy effectively captures light and limits understory development in the lower strata. The crowded stand conditions and dominance of shade-tolerant species (such as western hemlock) result in intense competition for light, water, and nutrients and have caused growth declines, especially where western hemlock predominates.

Old-growth forest remaining on City lands in the municipal watershed exist almost exclusively on steep rocky slopes. These areas have multiple age classes and multi-layered canopies, with high numbers of large snags and weathered live trees. Most of these stands are in the middle to upper elevations of the watershed and provide high habitat value for species that depend on late-successional forest structures. USFS data put these stands in the range of 600 to 800 years of age.

Approximately 3 percent of all inventoried trees are snags (standing dead trees), which results in about 1 snag per 10 acres. Snags in the managed stands are generally small and arise from competition mortality due to the crowded growing conditions; large snags are

TABLE 4-2.
DISTRIBUTION OF SITE CLASS BY ACRES IN THE MUNICIPAL WATERSHED

Site Class	Site Index[a]	Inventoried Acres	% Forested Acres[b]
I	136+	—	0
II	116—135	12	0.2
III	96—115	1,777	25
IV	76—95	2,067	29
V	56—75	1,168	16
Total		**5,024**	**70**

a. Site index is the average height of dominant trees at age of 50 years .
b. Calculated as percent of 7150 forested acres in 2006.

Young, dense stands in the "competitive exclusion" stage of forest development result in intense competition for light, water, and nutrients and have caused reduced tree diameter growth.

rare in the managed stands. The average snag is 9 inches in diameter and 30 to 40 feet tall. Seventy-eight percent of the snags are either western hemlock or Douglas-fir. Old-growth snags average 23 inches diameter and 45 feet tall.

Downed wood is abundant in most stands, although the distribution is variable and the size classes are generally small. Downed wood is distributed with highest concentrations in the draws and near former yarding corridors and landings. Most of the larger down wood is in lengths of 12 to 40 feet rather than whole trees and is in advanced stages of decay, with the exception of western redcedar (*Thuja plicata*). Most of the 12-inch and smaller material represents slash from pre-commercial thinning. Approximately 44 percent of the down wood is 12 inches or less in diameter, 46 percent is 13 to 24 inches and 10 percent is over 24 inches.

Indicators for forest habitat structure types as classified by Johnson and O'Neill (2001) are shown in Table 4-3. The area of each structure type in Table 4-3 was determined from the 2006 forest inventory. Map 8 shows the habitat classes by tree size and canopy layers.

Forest Disturbances

No large-scale natural disturbance, damage, or disease agents were noted during the inventory. Small areas of fir-fireweed rust are infecting some of the younger stands of silver fir. Dwarf mistletoe is not extensive, but does infect some stands and is heavy in small areas. On the lower, south facing slopes where Douglas-fir is more common, laminated root rot is starting to show as pockets of dead trees. Armillaria root disease is also present in small amounts. The most commonly observed tree damage is due to black bear cambium feeding or severe weather. Pistol butting due to snow creep is common in the higher elevation stands, as is red flagged foliage from winter desiccation. Douglas-fir was inappropriately planted in some higher elevation stands where it is growing in extremely poor forms due to snow damage.

TABLE 4-3.
FOREST HABITAT CLASSES BY FORESTED ACRES

Habitat Class	Tree Diameter (inches)	Tree Canopy Cover (%)	Tree Canopy Layers	Forested Acres
Grass/Forb				
Open	NA	<10	NA	37
Closed	NA	<10	NA	6
Shrub/Seedling				
Open	<1	<70	1	83
Closed	<1	>70	1	0
Sapling/Pole				
Open	1-9	10-39	1	81
Moderate	1-9	40-69	1	323
Closed	1-9	>70	1	3057
Small Tree, Single Story				
Open	10-14	10-39	1	0
Moderate	10-14	40-69	1	538
Closed	10-14	>70	1	1543
Medium Tree, Single Story				
Open	15-19	10-39	1	0
Moderate	15-19	40-69	1	0
Closed	15-19	>70	1	0
Large Tree, Single Story				
Open	20-29	10-39	1	0
Moderate	20-29	40-69	1	227
Closed	20-29	>70	1	0
Small Tree, Multi-Story				
Open	10-14	10-39	>2	0
Moderate	10-14	40-69	>2	75
Closed	10-14	>70	>2	660
Medium Tree, Multi-Story				
Open	15-19	10-39	>2	0
Moderate	15-19	40-69	>2	0
Closed	15-19	>70	>2	0
Large Tree, Multi-Story				
Open	20-29	10-39	>2	50
Moderate	20-29	40-69	>2	387
Closed	20-29	>70	>2	68
Giant Tree, Multi-Story	>30	>40	>2	0

Source: Johnson and O'Neil (2001); Forested acres from 2006 Forest Inventory.

USFS Land within the SFTMW

The forest cover on National Forest System lands is in many respects similar to that of the SPU-owned lands except that there is substantially less of this area in very young forest and more in old-growth. Steep rocky areas make up a larger percentage of the National Forest System lands than the municipal watershed as a whole. The old-growth forests in this area are typical of the very old, multi-age Pacific silver fir and western hemlock dominated stands of the Cascade Mountains. This forest type provides the late-successional habitat elements, such as complex canopy structure and decadence. Not far above the valley floor, Alaska yellow cedar becomes a significant forest component on National Forest System lands, although it was not found in the inventory on the City-owned part of the SFTMW. At higher elevations, mountain hemlock becomes common. Higher on the south facing slopes, sub-alpine fir is found in open talus areas. In previously harvested young forest at lower elevations, it appears that no pre-commercial thinning has occurred.

Downed wood is abundant in most stands, though only 11% is over 24 inches in diameter such as that shown in this photo.

LEGAL REQUIREMENTS

The Washington State Forest Practices rules (WAC 222) regulate forest activities in the SFTMW. SPU must follow these rules when conducting forest management activities including timber harvest, reforestation, use of forest chemicals, road building, and any work in riparian corridors.

ISSUES

Past forest management has drastically disturbed forests in the watershed and altered natural ecosystem functions in the watershed, such as forest habitat, productivity, and water cycle regulation. While the primary management goal for the SFTMW is to provide domestic water, the City also has a strong commitment to provide other ecosystem services, such as habitat and carbon sequestration. The restoration of late-successional forest conditions could significantly improve

many ecosystem functions that provide those services.

The clear-cut harvesting of old-growth forests has dramatically changed the watershed landscape, which now supports a forest age class distribution dominated by young forest stands with remnants of old-growth forest. The tree species distribution has a preponderance of shade-tolerant species that maintain dense forest canopies and reduce biological diversity. Studies from elsewhere have shown that young forest ages and limited tree species composition results in homogeneous forest structural conditions that have lower habitat value, biodiversity and summer base flows in the tributary streams (Perry 2007).

Clear-cutting the old-growth forests also reduced the number of large residual standing and down dead trees. These residual structures provide important ecosystem functions, such as habitat, nutrient cycling, and development of soil organic matter. The low biological diversity resulting from these changes in the forest landscape may reduce the resilience of the ecosystem to withstand or recover from further disturbance or adapt to gradually changing environmental conditions that occur from climate change.

Many of the roads that were constructed to harvest the old-growth forest in the basin have been removed because of their continued sediment production from the disturbed hill slope. In particular, the removal of mid-slope roads and roads on steep slopes in the southeast portion of the basin create operability constraints for possible forest management. These areas must be excluded from active management or are considered for hands-only restoration treatments.

The setting of the SFTMW between industrial forest lands and National Forest creates a strong contrast in forest age distribution and structure on the landscape. This situation places a greater importance on the management of SFTMW forest lands to create a landscape more effective in fostering biodiversity and providing resilience in the face of environmental changes and disturbance.

OPTIONS ANALYSIS

The full range of forest management options from passive management to timber management was modeled in order to provide information for decision-making. Four forest management options were evaluated based on ecological, economic, and social criteria.

- **No-Action**—This option would continue the current approach of no active management. Watershed forests would be passively managed and would eventually develop into late-successional habitat.
- **Habitat Development**—This option would facilitate the recovery of ecosystem functions and develop late-successional forest attributes more quickly than the No-Action alternative by improving forest habitat through thinning, canopy gap creation, snag creation, down wood augmentation, and planting. The goal would be to increase habitat for species dependent on late-successional forest structures. Old-growth forest remnants, inaccessible areas, and unstable slopes would not be manipulated under this option. The sale

of timber from thinning operations would subsidize restoration treatments to a limited extent.

- **Sustainable Harvest and Habitat Development**—This option would develop uneven-age forest structures to sustain timber harvest over time and develop forest habitat complexity. Forest structures would be changed through group selection, matrix thinning, and longer rotations (i.e., harvesting forest patches at older ages than normally done under commercial forest management). Habitat complexity would be increased by changing forest structures and planting to increase species composition. Thinning would increase future timber yield and revenue possibilities. Areas would be excluded from timber extraction for habitat development, access limitations, hydrologic concerns, environmental impacts, and economic feasibility of timber harvest.
- **Sustained Timber Yield Management**—This option would maintain even-aged forest structures and a balanced age class distribution (all forest ages distributed on the landscape), with goals to maintain or increase timber yield over time and generate revenue from commercial timber harvest. Young stands would be thinned to increase timber yield and select for commercially desirable species. Stands would be regenerated through clear cutting where possible and planted. Rotation age would range from 70 to 100 years, depending on site productivity. Some areas would be excluded due to access limitations, hydrologic concerns, and economic feasibility of timber harvest.

The options were modeled using the OPTIONS Model and Stand Projection System Forest Projection Systems (DR Systems, Nanaimo, B.C.) for post processing and economic analysis. Results were evaluated based on the following factors:

- Structural classification of forest types
- Timber harvest volumes
- Projected habitat elements (deciduous species, tree size)
- Projected revenues
- Projected costs
- Management limitations and opportunities
- Fire hazard analysis and risk management recommendations
- Carbon sequestration opportunities and limitations.

Each management option was projected over 200 years in 10-year intervals to evaluate sustainability of the silviculture regimes and structural development of forests. Each model included the following management constraints:

- Management Zones—Four management zones were delineated. Under each modeled option, these zones were managed with a consistent balance between late-successional reserve and active forest management (see Map 9).
- Maximum Disturbance Levels—Each subbasin was assigned a maximum area of open canopy and thinned canopy per decade in order to minimize the adverse effects of rain-on-snow events.

TABLE 4-4.
FOREST RESTORATION TREATMENTS
AND FOREST STAND TYPES TO WHICH THEY APPLY

Treatment	Description	Forest Stand Type or Element
Restoration Thinning	Thinning to 150 - 250 trees per acre, creating canopy gaps	Young dense forest 15 to 40 years old and 15 to 40 feet tall
Ecological Thinning (Type 1 and 2)[a]	Variable density thinning to 100 - 240 trees per acre, including canopy gaps and unthinned skips	Older dense forests with closed canopy
Planting	Planting 200 site-specific trees per acre of western redcedar, red alder, big leaf maple or other appropriate species	Canopy gaps
Understory Thinning	Thinning to 250 trees per acre	Young dense trees in understory
Habitat Enhancement	Top or girdle clusters of 4 large trees per acre	Older dense forests with few snags

a. Ecological Thinning Types 1 and 2 differ in stand condition to which they are applied and also in thinning intensity. See Appendix A, Table 1 for details.

- Riparian Management Zones—Treatments in riparian management zones were assigned by stream type to balance the positive and negative effects of thinning and harvesting on aquatic habitat and water quality, and to comply with WDNR Forest Practices Rules.
- Adjacency Rules—In the "Sustainable Harvest and Habitat Development" and "Sustained Timber Yield Management" options, harvest scheduling was restricted to minimize the extent of adjacent harvest units, based on WDNR Forest Practices Rules.
- Harvest Levels—A maximum sustainable 10-year harvest level was assigned to each option. Harvest level in the "Sustained Timber Yield Management" option was highest, followed by the "Sustainable Harvest and Habitat Development" and "Habitat Development" options. No harvest was scheduled in the "No-Action" option. Actual annual harvest levels were allowed to fluctuate within the remaining management constraints.
- Treatment Prescriptions—Detailed prescriptions for regeneration, stocking density control, and habitat enhancement were assigned for each option (see Table 4-4 and Appendix A, Table 1). The prescriptions were adjusted to accommodate stand dynamics in different species groups and site classes.
- Buffer Zones—Non-forest habitat was buffered (i.e. no forest management activity) to reduce effects of harvest activities on headwater streams, wetlands, rock outcrops, old-growth forest, and the reservoir. These buffer zones are distinct from Riparian Management Zones, which allow management activity in different options.
- Operability Zones—Regeneration and ecological thinning treatments were

allowed only in areas that could be accessed by ground-based equipment, cable yarders, and helicopter yarding. Restoration thinning (in forests between 15 and 40 years old) was allowed in the remaining hand-equipment only areas where there was no access for other equipment types.

Revenue flows were based on 2007 implementation costs and timber values. Fire hazard rating was based on topography and forest structure. Carbon sequestration was calculated from live and dead tree biomass and on-site and off-site decay. Sequestration rates for the "Sustained Timber Yield Management" option were subtracted from the other three options to determine how much increased sequestration would be achieved if forest management entailed harvest below a level consistent with the regulatory standard).

Habitat development over the projection period was based on the forest structure types by Johnson and O'Neil (2001) (Table 4-3). Forest habitat was assumed to change with increasing tree size, changing canopy cover, and development of canopy layers. Canopy cover was calculated and used in the model based on its relationship with relative stand density. A deterministic model for the development of multiple canopy layers was developed based on regeneration treatments, overstory density, and forest age. Results of the model projections are summarized in Appendix A.

RECOMMENDED ACTIONS

The SFTMW lies within the King County Forest Production District, and forest products remain an important element of the agricultural sector of the regional economy. The triple bottom-line potential for continued industrial forestry in the SFTMW is limited, however, in the face of current anticipated harvest costs and foregone potential ecosystem services. Based on the modeling and evaluation of forest management options, a policy decision was made to proceed with detailed development of the "Habitat Development" option. This option is considered to be the most consistent with other City environmental policies and management strategies. Additional modeling work has been conducted to evaluate differences between the "Habitat Development" option and the "No-Action" option regarding net costs to the City and net gains on ecosystem services, such as habitat functions and carbon sequestration. The remainder of this section describes the recommended actions under the "Habitat Development" option.

Forest Restoration Approach

The forest management approach under the "Habitat Development" option focuses on restoration of forest habitat and the long-term development of late-successional forest structures. Protection and enhancement of hydrological processes are supported under this approach through road decommissioning, riparian protection, limiting canopy gap size and frequency, and creating resilient forest structures. The active restoration approach would facilitate the interaction of forest development processes with small-scale disturbances such as wind, insects, and pathogens for the long-term development of late-successional forest conditions. This option would obtain revenue from selling

surplus timber from thinning and gap creation to support the cost of management activities, while retaining and augmenting snags and down wood to fulfill ecological functions. Specific management objectives are as follows:

- Promote the development of late-successional forest structures through reducing tree competition, initiating canopy layers, increasing spatial heterogeneity, retaining down wood, and promoting decadence.
- Provide wildlife habitat elements by increasing tree size variation, developing more foliage layers within stands, retaining down wood and dead standing trees, and promoting and planting minor species.
- Sell surplus trees, after downed wood and snag retention standards are met in thinning treatments of commercial size trees, to offset costs of restoration activities.
- Maintain reserve areas including non-managed remnants of old growth, inaccessible areas of the watershed, and unstable slopes.

Decision Model for Restoration Treatments

Recommendation FOR1—While most of the second-growth forests in the SFTMW would benefit from restoration treatments, certain areas will be prioritized because they are more likely to respond to restoration treatments or will provide greater functional value once restoration has taken effect. Treatments for specific areas will be determined through the following steps:

- Using defined management zones with particular restoration goals
- Identifying areas of potential productivity that will respond differently to restoration
- Identifying stand conditions that will respond to restoration treatments.

Management Zones

Four management zones were delineated at the landscape scale (Map 9). Forests in the Connectivity and Valley Bottom Management Zones will be prioritized for forest restoration treatments because they are nearest to existing old-growth forests on the National Forest System lands. Developing forests with greater habitat values, such as vertical and horizontal heterogeneity and increased species diversity, will most effectively create habitat connectivity with residual old-growth forests. Forests in the West End Management Zone in the western part of the municipal watershed are surrounded by young forests on industrial forest lands and would provide fewer habitat connections, so this management zone is lower priority for treatment. Previously harvested areas in the Reserve Zone are mostly inaccessible to equipment access but would likely benefit from restoration thinning once appropriate stand structures have developed.

Productivity

Research has shown that structural elements resembling late-successional forest conditions develop sooner in higher productivity second-growth forests, regardless of intervention (Larson et al. 2007). Consequently, forests on lower productivity sites (Site Class IV and V) should be prioritized for restoration. Currently, most forests on low productivity

sites are young (15 to 40 years) and will be prioritized for restoration thinning.

Stand Condition

Forest structure and composition at the stand level will determine whether restoration is indicated and whether the forest community is going to show the desired response to restoration treatments. Detailed structural indicators that would trigger restoration planning are given in Table 4-4 and in Table 1 of Appendix A. Young stands of shade tolerant western hemlock and Pacific silver fir are likely to undergo prolonged phases of competitive exclusion with reduced habitat and biodiversity values. Such stands are likely to respond to restoration thinning during stages of maximum height growth (age 15 to 40 years) with increased diameter growth, crown development, and retention of higher levels of plant species diversity; these young stands will be prioritized for treatment.

Ecological Thinning
Thinning treatments for stands with closed single-layer canopies and high stand density, designed to reduce tree competition and increase structural complexity. The new canopy gaps are planted with minor species (western redcedar, red alder, and big leaf maple) to increase canopy layers.

At later stages of stand development, high tree density and closed canopies slow the transition of stands into structurally diverse multi-layered canopies. Depending on forest structural conditions in older second-growth stands, one of two ecological thinning treatments may be implemented (Appendix A, Table 1):

- **Ecological Thinning 1—**Stands that approach maximum stand density and have undergone crown differentiation can be thinned to reduce competition, release understory trees, and open canopy gaps to introduce new canopy layers. These stands have higher priority for Ecological Thinning (Ecological Thinning 1, Appendix A, Table 1).
- **Ecological Thinning 2—**Stands that show less crown differentiation but approach high stand density will benefit from thinning of smaller trees (thinning from below) to reduce competition but are less likely to develop multiple canopy layers. These stands will be thinned in high priority areas to increase crown development and introduce new cohorts in canopy gaps.

Forest Restoration Treatments

The forest habitat restoration treatments (Map 10) are designed to improve forest habitat conditions, nutrient and water cycle regulation, productivity, and biodiversity. Habitat restoration treatments are based on a body of knowledge that is described in depth in the *Upland Forest Strategic Plan for the Cedar River Municipal Watershed* (LaBarge et al. 2008). These treatments include planting minor tree species, thinning young dense stands of conifers, variable density thinning in older forests, understory thinning, and habitat enhancement through retention and creation of standing dead and down wood.

Given the current forest age-class distribution in the municipal watershed, forest restoration treatments will be scheduled over a period of 70 years to achieve the desired treatment level. Silviculture prescriptions are described in Table 4-4 and in more detail in Appendix A. These prescriptions were used in the OPTIONS modeling analysis and will be applied to all eligible second-growth forests in the watershed. However, the prescriptions may be adapted to site-specific conditions by a restoration project team during plan implementation. The proposed area for each

type of restoration treatment is summarized in Table 4-5. The following sections provide further detail for each treatment type.

Coordination with Other Activities

Recommendation FOR2—Forest restoration treatments will be coordinated in different ecosystems and among other management activities such as road decommissioning and aquatic restoration, similar to how forest restoration is planned in the Cedar River Municipal Watershed (Erckmann et al. 2008). Such coordination will help to reduce operational constraints, such as when riparian thinning is coordinated with upland thinning. Therefore, forest restoration in the second-growth forests adjacent to streams in the Valley Bottom and Connectivity Zones are prioritized where riparian and aquatic restoration work is planned. Forests in the Skookum Creek drainage will be prioritized for forest restoration treatments to coordinate with road decommissioning and aquatic restoration schedules.

Multi-disciplinary teams with representatives from a variety of disciplines, including forest ecology, fish and wildlife ecology, hydrology, engineering, and operations, should be formed whenever appropriate to participate in the planning and implementation of all restoration projects proposed for the municipal watershed.

Restoration Thinning

Recommendation FOR3—Restoration thinning treatments are designed to reduce the density of trees in young stands (less than 40 years) and create irregular patterns of tree distribution by incorporating canopy gaps. This type of stand structure has been shown to increase tree diameter growth, increase cover and diversity of understory vegetation, and retain enough trees for future functional dead wood. Increasing tree diameter growth during early stand development stages has been shown to reduce the risk of wind and snow damage.

Selective thinning by species provides the opportunity to change competitive pressure on minor species including deciduous trees, thus maintaining tree species diversity throughout forest development.

Of the 3,350 acres of stands currently under 40 years of age, 1,114 acres are planned to receive restoration thinning (see Table 4-5). The remaining young stands have lower tree density, are in reserve areas, or will be older than 40 years by the time they can be thinned. Sixteen percent of the total forested area will be treated with restoration thinning (where no trees are cut), the majority of which is planned for the first two decades, following the decision model for restoration treatments. This front-loaded thinning schedule will allow more young stands to develop under low density conditions with more diverse species composition. Restoration thinning units are located mostly in young stands on the south side of the reservoir and in the Skookum Creek drainage.

Restoration Thinning
Reduction of tree density in young stands and creation of irregular patterns of tree distribution by incorporating canopy gaps. This has been shown to increase tree diameter growth, increase cover and diversity of understory vegetation, and retain enough trees for future functional dead wood.

Ecological Thinning

Recommendation FOR4—Ecological thinning treatments are planned in stands with closed single-layer canopies and density of more than 260 square feet basal area per acre (see Appendix A, Table 1). Variable density thinning treatments, including both ecological thinning 1 and 2, (See

TABLE 4-5
ACRES OF RESTORATION TREATMENTS PLANNED BETWEEN 2010 AND 2080

	Ecological Thinning 2	Ecological Thinning 1	Planting	Restoration Thinning	Riparian Thinning
2007-2016	389	186	113	451	133
2017-2026	539	175	124	292	83
2027-2036	204	285	134	11	17
2037-2046	579	22	67	54	24
2047-2056	463	146	105	0	12
2057-2066	587	106	101	165	7
2067-2076	564	52	77	67	6
2077-2086	10	25	11	71	0
Total Acres	**3,336**	**996**	**732**	**1,114**	**282**
Percent of Forest	47%	14%	10%	16%	4%

Recommendation FOR1) are designed to reduce canopy tree competition and increase structural complexity over 60 percent of each treatment area, removing between 30 and 45 percent of the standing tree volume.

The remaining 40 percent of the treatment area will be equivalent amounts of canopy gaps 0.5 to 1 acre in size (where nearly all trees are cut) and unthinned skips (where trees are cut) to retain high density patches. The canopy gaps will be planted with minor species (western redcedar, red alder, and big leaf maple) to increase canopy layers in the total treatment area. Forest stands with high stem density and low average stem diameter will be treated with lower thinning intensity (fewer trees removed) to reduce competition and retain stand structural stability against wind disturbance.

There are currently 3,000 acres of forest eligible for ecological thinning, in the City-owned portion of the watershed, ranging in age from 41 to 70 years, and another 1300 acres of forest will develop into forests eligible for future ecological thinning. A minimum tree size and density condition is required to make this treatment feasible (Appendix A, Table 1). Due to the current structure and species composition, most of the stands eligible for ecological thinning are dominated by Douglas-fir and are planned to be thinned during the first two decades of restoration activities. This is reflected in the priority for treatment for stands in the Valley Bottom and Connectivity Management zones.

Beginning in the second decade of treatments, more of the hemlock dominated stands will have reached stand densities and volumes that will make them eligible for ecological thinning. Currently young stands dominated by Pacific silver fir and noble fir (true firs) will increase in density and tree size and become eligible for ecological thinning during the third decade of implementation (see Appendix A, Table 2).

Most of the true fir stands will have received restoration thinning treatments during younger stand ages. A total of 4,300 acres of ecological thinning is planned over 70 years, reaching 61 percent of the forest area (Table 4-5).

Forest habitat restoration treatments are designed to improve forest habitat conditions, nutrient and water cycle regulation, productivity, and biodiversity.

Planting and Understory Management

Recommendation FOR5—Many thinned stands are expected to naturally initiate a new cohort of shade-tolerant understory trees (e.g., western hemlock, Pacific silver fir) following thinning. However, canopy gaps will be actively planted to introduce less tolerant species (e.g. Douglas-fir, western redcedar). The combination of planted species will vary among sites with different potential productivity and will include deciduous trees. Ten percent (732 acres) of the total forested area will be planted following gap creation during ecological thinning over 70 years. Subsequent understory thinning may be necessary to reduce competition from naturally regenerated shade-tolerant trees, both in the planted gaps and in the thinned areas.

Riparian Thinning

Recommendation FOR6—Riparian thinning is planned in subbasins where improved riparian functions will have an effect on stream processes. The treatments are designed to retain shade to the stream and increase current and future in-stream large woody debris (LWD). By felling trees directly into the stream, the added LWD will provide immediate benefit by reducing sediment transport yield. A total of 282 acres of riparian thinning is planned, most of which will occur during the first two decades of plan implementation. Riparian thinning applies to the riparian management zones (RMZ) along streams, which change in width and treatment depending on stream type (Table 4-6).

Restoration thinning is planned in the Inner and Outer RMZ, as well as in the 50 foot Core Zone, outside the channel migration zone. In stands younger than 40 years, restoration thinning treatments will focus on reducing competition to increase individual tree growth and shorten the time until the riparian forest will produce LWD of functional size. Riparian thinning of stands younger than 40 years is included in the restoration thinning acreage.

Ecological thinning without yarding of up to 20 percent of the stand volume is allowed under Forest Practices Rules in a 50-foot RMZ along perennial streams in order to augment coarse woody debris (CWD). Thinning and yarding 20 percent of the

TABLE 4-6.
RESTORATION TREATMENTS IN RIPARIAN MANAGEMENT ZONES

	Approximate 50-Foot Outer RMZ	Approximate 50-Foot Inner RMZ	50-Foot Core Zone
Wetlands and Type F and Type S streams	Restoration and Ecological Thinning	Restoration Thinning and Cut-and-Leave 20% Volume for LWD	Restoration Thinning Only, No Gaps
Type Np Streams	No Action Planned	Restoration Thinning and Cut-and-Leave 20% Volume for LWD	No Action Planned
Type Ns Streams	No Action Planned	No Action Planned	Restoration Thinning Only, No Gaps

Type F Streams = fish-bearing streams
Type S Streams = shorelines of the state
Type Np Streams = perennial streams
Type Ns Streams = seasonal streams
RMZ = riparian management zone
LWD = large woody debris

volume plus thinning 20 percent of stand volume for CWD is allowed in a 100-foot RMZ along fish-bearing streams, shorelines of the state, and wetlands. An 80-foot wide reserve zone along the reservoir is excluded from all forest restoration treatments.

PREDICTED MANAGEMENT OUTCOMES

Development of Forest Structure Classes

In order to evaluate habitat improvement, the development of forest structure in the model projections was evaluated using the forest habitat structure classes by Johnson and O'Neil (2001). Each forest stand delineated during the inventory was assigned a forest structure class based on average tree diameter, number of canopy layers, and canopy closure. Tree growth and stand development were then modeled using the OPTIONS Model and Stand Projection System (SPS), and stands were reclassified after each projection period.

Map 8 shows the current distribution of structure types (year 2007). Figure 4-2 shows the projected development of forest habitat types over the 200-year projection period following restoration management.

While natural forest development ultimately leads to structurally diverse forests that provide habitat for species dependent on late-successional forest conditions, this development may not occur before 300 years in some forest types. Reaching these complex structural conditions depends largely on small-scale natural disturbance from wind, pathogens, and insects, and its timing is relatively unpredictable. In order to set forest stands on a trajectory of understory development and vertical differentiation, ecological thinning treatments are applied to lower canopy density, encourage crown development, and stimulate natural regeneration of understory. The expected transition from single-layer stands to multi-layer stands is shown in Figure 4-3. Planting canopy gaps will increase the area of mixed coniferous-deciduous forest over time, providing important elements of biodiversity.

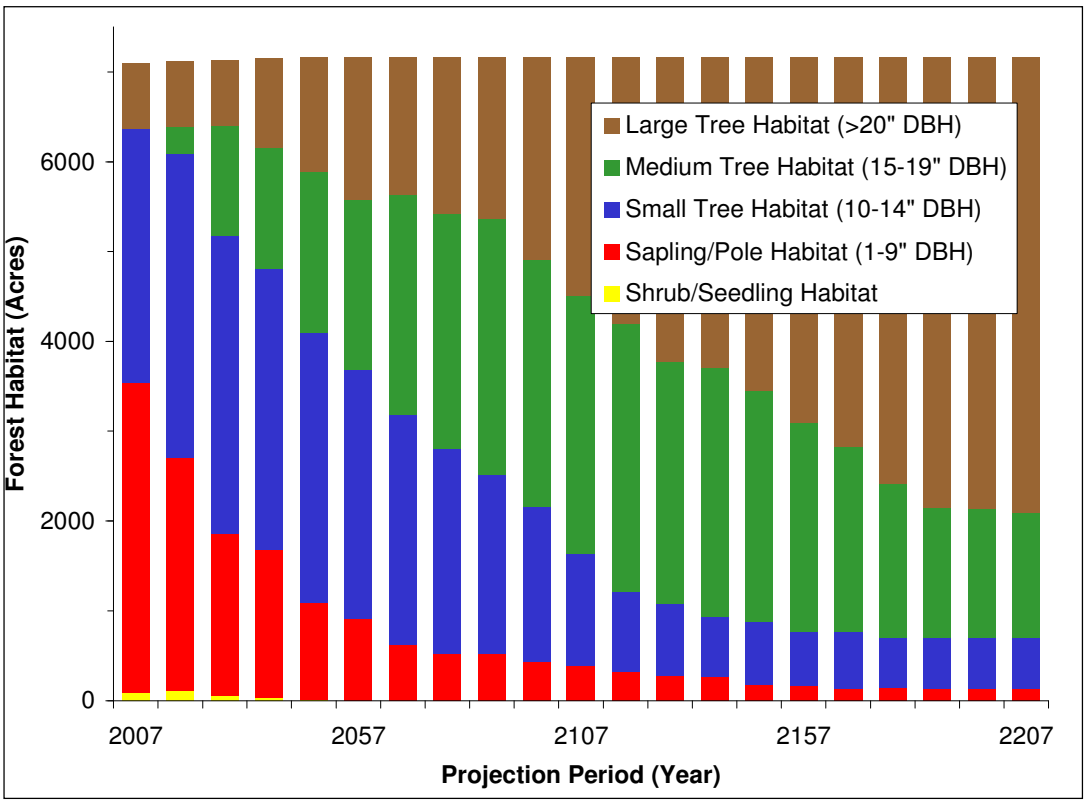


Figure 4-2. Projected Development of Forest Habitat Types.

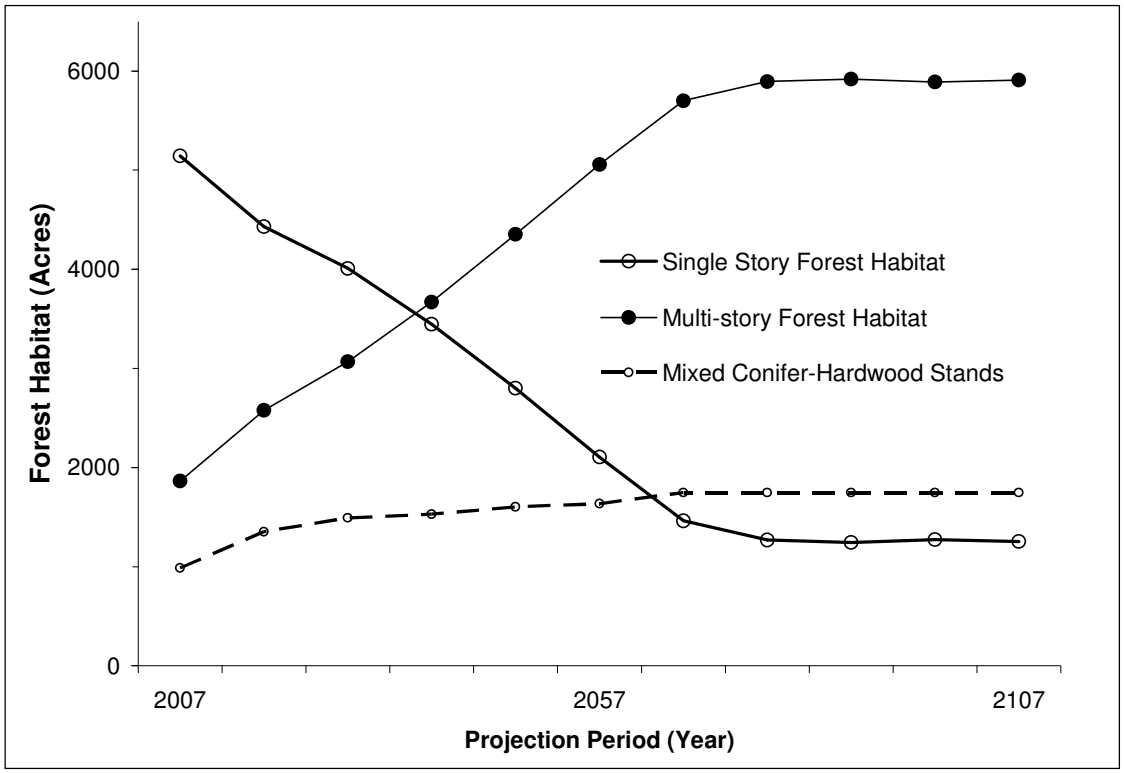


Figure 4-3. Expected Transition from Single to Multi-Layer Canopies During the Next Century with Treatment.

The modeling projection shows the area of mixed forests to increase by 77 percent, from 990 acres in 2007 to 1,750 acres in 2087. This projection does not include the assumption that many stands that are currently of mixed species will revert to coniferous stands.

Carbon Sequestration

Carbon sequestration, which offsets greenhouse gas emissions from human activities, was estimated over the projection period. Sequestration rates were based on changes in forest biomass volume over time, timber harvest, and emissions from on-site decomposition of slash and off-site emissions of forest products. The analysis used methodology described in Smith (2004).

The "Sustained Timber Yield Management" option was used as a baseline and carbon credits were calculated as the difference in net sequestration between the baseline and other management options. Net sequestration is calculated as total sequestration minus emissions from slash and forest products. The "Habitat Development" option had an annual net sequestration rate of 4.43 metric tons of carbon dioxide equivalents (CO2e) per acre per year, compared to the baseline of 3.41 metric tons. This amounts to 1,994 tons of net carbon per year above the baseline for the total forested area. The net sequestration rate of the "Habitat Development" option was second only to the "No-Action" option (5.45 tons CO2e per acre per year).

Differences in carbon sequestration among management options should be evaluated in context of the full suite of benefits the forests in the SFTMW provide. According to Batker (2005), the forests in the Tolt Watershed provide significant ecosystem services such as habitat disturbance prevention, water and nutrient cycle regulation, aesthetic values, and many others. Despite lower carbon sequestration rates estimated for the "Habitat Development" option than for the "No-Action" option, active restoration in the SFTMW forests would create a net benefit in ecosystem services, primarily because of this option's positive impact on sediment process and habitat development. More detailed information on the Ecosystem Service Valuation is provided in Appendix A.

Fire Hazard

Disturbance through forest fire poses a risk to water supply management in the SFTMW. The natural fire regime in the watershed is characterized by very infrequent high intensity fires of large extent. Despite the fact that natural and human caused ignition sources are rare in the watershed and severe fire weather conditions occur only during brief periods in the summer, certain stand structural conditions can increase fire hazard, such as increased ground and ladder fuels.

As part of the forest management options analysis, fire hazard conditions were estimated for steep south-facing slopes where topography and fuel moisture conditions are most likely to propagate active crown fires. Despite the accumulation of slash after restoration thinning and creation of ladder fuels after ecological thinning, no areas of high fire hazard were identified, and the average increase compared to the No-Action option was only 118 acres of moderate fire hazard during the management period. It was

determined that this change in fire hazard conditions did not warrant deferring from the "Habitat Development" option.

ADDITIONAL CONSIDERATIONS

Adaptive Management

The forest restoration approach in the SFTMW follows guidance from the Cedar River Municipal Watershed (CRMW) Habitat Conservation Plan forest habitat restoration program. The *CRMW Upland Forest Habitat Restoration Strategic Plan* (LaBarge et al. 2008) describes this program and its implementation within an adaptive management framework. While funding exists in the CRMW for research and monitoring in an adaptive management framework, a less resource intensive strategy is built into the SFTMW Plan for monitoring. Knowledge gained through the CRMW forest restoration program will be applied to the SFTMW as forest habitat restoration proceeds.

While the SFTMW forest restoration recommendations rely upon current detailed forest inventory information, they also draw heavily from the OPTIONS model growth projections. There is uncertainty associated with modeling exercises in general, but the trend of improving forest habitat with silvicultural interventions is well documented in the forest research literature. Future data acquisitions in the SFTMW will be leveraged to update forest development model projections to ensure that adaptive forest management occurs. These data acquisitions include restoration project compliance monitoring data that is collected to ensure implementation contract compliance, as well as new inventory data that is collected for the purposes of conducting project appraisals. A portion of these data collection points will be sampled periodically into the future, thereby establishing a low-intensity set of permanent inventory points to track long-term forest development across the watershed.

Another important issue is the uncertainty regarding how forests will respond to ongoing climate change. SFTMW and CRMW watershed ecologists will identify key ecosystem elements and processes to monitor to detect changes. For example, annual monitoring of mortality trends may be conducted in collaboration with Washington State Department of Natural Resources. Potential mitigation strategies include planting of diverse tree species and creating a more heterogeneous age structure to improve forest resilience in the face of climate change.

Further details on data collection and a flow chart for the adaptive management cycle are available in Appendix A.

Large Scale Disturbances and Potential Impacts from Neighboring Properties

The effects of large-scale disturbances such as fire, insects and introduced pathogens on forest resources were not included in this analysis. The forest management activities of adjacent landowners create a fire risk for the SFTMW by actively managing young dense forest on the border of the municipal watershed. Forest insect populations in temperate forests have had unprecedented population dynamics in recent years and may pose a risk to forests in the basin. Past and

present introductions of forest pathogens have significant effects on forest communities, and future impacts are difficult to predict.

A change in forest resource management on neighboring properties could affect the current designation of management zones in the SFTMW. A shift from industrial timber management toward ecosystem management could affect the landscape-scale priorities for restoration treatments outlined above. However, anticipating forest land management decisions on neighboring properties is not in the scope of this management plan and was not considered in the analysis. Similarly, the restoration activities described here assume access to remote sites, sometimes through neighboring properties. Restoration priorities may change if access through neighboring properties should become restricted.

Revenue Projections

Revenue from the sale of surplus timber may fluctuate due to changing prices for forest products in regional markets. In recent years, some forest products have seen increasing prices while others have declined. It is therefore uncertain if the projected revenue flow from the sale of timber from ecological thinning activities will be achieved. Analysis of future log markets, however, lies outside the scope of this management plan analysis, and 2007 mid-year timber values were used for the projections